EFFECTIVE DISPERSION OF CARBON NANOTUBE IN EPOXY GROUT FOR STRUCTURAL REHABILITATION

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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree of Civil Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Industri pada masa kini lebih gemar menggunakan sistem pembaikan komposit untuk membaiki saluran paip berbanding dengan pembaikian keluli konvensional. Mekanisme kaedah pembaikian ini biasanya terdiri daripada tiga komponen iaitu pembalut komposit, dempul dan pelekat. Walau bagaimanapun, standard reka bentuk pembaikan saluran paip pada masa kini hanya mengambil kira kekuatan baki paip yang rosak dan kekuatan pembalut komposit. Penyelidikan tentang fungsi dempul dalam mekanisme pembaikian paip adalah sangat terhad sehingga kini. Kajian ini berfokus untuk meningkatkan prestasi atau sifat mekanikal dempul dalam pembaikian saluran paip dengan mengukuhkan dempul melalui penambahan nanotube karbon (CNT). Peningkatan prestasi dempul telah dijalankan melalui perpisahan CNT di resin dempul dengan mesin *'three roll mill'*. Dalam ujian sifat ketegangan, CNT didapati merupakan satu bahan yang berkesan untuk meningkatkan kekuatan tegang dempul. Walau bagaimanapun, sampel yang diubahsuai dengan CNT menunjukkan penurunan kekuatan dalam ujian mampatan. Semua sampel yang diubahsuai CNT mempamerkan kekuatan mampatan yang lebih rendah berbanding sampel kawalan dan sampel yang dikalender. Kesimpulannya, CNT menunjukkan potensi untuk menjadi bahan yang sangat baik untuk meningkatkan sifat-sifat mekanikal bahan dempul. Walau bagaimanapun, dengan dempul yang mengandungi pengisi keluli yang bersaiz besar, penambahan CNT hanya dapat meningkatkan sifat tegangan manakala sifat mampatan bahan dempul telah terjejas berbanding sampel kawalan.

ABSTRACT

The industry nowadays is incorporating the composite repair system for repairing pipelines rather than the conventional steel repair. The mechanism of this repair method usually consists of three components which are the composite wrap, infill material and the adhesive. However, there have been very little researches on the function of the infill in the repair mechanism. This work is concerning the enhancement of the performance or the strength properties of the infill material in pipeline repair by reinforcing the putty with carbon nanotubes (CNT). The enhancement of the performance of the infill has been carried out by dispersing the CNT into epoxy resin with a three roll mill. In the mechanical properties testing, it is found that the CNT is an effective material to improve the tensile strength of the epoxy grout. However, the CNT-modified samples in the compressive properties test show a contrast to the tensile test. All the CNT-modified samples exhibit a lower compressive strength than the control sample and the milled down sample. In conclusion, CNT shows the potential to be a very good material to enhance the mechanical properties of epoxy grout, however, with this specific brand of epoxy grout that contains steel filler in the resin, the CNT only improve the tensile properties but the compressive properties of the epoxy grout has been compromised as compared to the control sample.

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LIST OF SYMBOLS

MPa	Mega Pascal
GPa	Giga Pascal
mm	Millimetre
μm	Micrometre
RPM	Revolution per minute

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
ASME	American Society of Mechanical Engineers
ISO	International Organization for Standardization
FRP	Fibre-reinforced Polymer
CNT	Carbon Nanotube
FESEM	Field Emission Scanning Electron Microscope
CIA	Central Intelligence Agency
NTSB	National Transportation Safety Board
FEA	Finite Element Analysis
UTS	Ultimate Tensile Strength
FLG	Few-layer Graphene
CB	Carbon Black
SWCNT	Single-walled Carbon Nanotube
DWCNT	Double-walled Carbon Nanotube
MWCNT	Multi-walled Carbon Nanotube
TEM	Transmission Electronic Microscope
UTM	Universal Testing Machine
EDX	Energy-disperse X-ray Spectroscopy

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

According to The History of Pipelines in 2016, pipeline started being used as a mean to transport oil and gas raw material as the first commercial oil well are drilled by Edwin Drake in 1859. Pipeline started out as simple and short pipe that are used to transport crude oil from the well to the nearby tanks or refineries. Before iron pipeline were being used by the oil industry, goods and raw material are transported by teamster wagon, wooden pipes and rails. The growing oil business has caused a greater need for transportation of products to the markets. Steel pipes started to be utilized from the 1860s as the pipeline business grew and the quality control in the piping industry has become a reality (Pipeline 101, 2016b).

However, as time passes, the pipeline will age hence, deteriorate. This has led to the development of the methods to repair the pipeline. In the early days of pipeline repairs, the repair method are rather straight forward which is to cut off the damaged section and replace it with a new section of pipes. Succeeding this method is the conventional steel sleeve repair system where a steel sleeve are welded or clamped onto the existing pipe to cover and increase the load bearing capacity of the damaged section of the pipe. This method has its own weaknesses being that it does not help in suppressing of the bulging of the defect area without grouting it as the thickness of the pipe decreases due to corrosion, etc.

Since the conventional repair system is very rigid and flawed, researchers have been working tirelessly to develop a superior system to repair pipelines. In the 1970s, the Research and Development division of the British Gas Corporation has developed a technology that is the epoxy technology to repair damaged pipelines (Bryson et al., 2015). Subsequent to this development, pipeline operators around the world were able to capitalize on this epoxy technology. Despite, most of the pipeline industry did not incorporate this method immediately.

Confidence in the technology begin to be shown in early 2001 as the first land-based epoxy hot tap are installed (Bryson et al., 2015). Since then, the number of pipeline operators using fibre reinforced polymer composite repair system to repair pipelines has been swelling. This has caused the recent development of design codes for the design of the repairs of pipelines such as ASME PCC-2 and ISO/TS 24817. These codes were developed to standardize the design method of composite pipeline repair. This has also made quality control in this field a reality as pipeline operators has increasingly utilizing this method of repair.

1.2 Problem Statement

Although the fibre reinforced polymer (FRP) repair method requires much less equipment and are less bulky in most of the cases, it still requires an abundant amount of space to complete a repair of a damaged pipeline especially underground pipelines. This has sparked the growing interest of the industry to improve the current method of composite pipe repair system. Consequently, the industry are now collaborating with researchers to find a way to enhance the repair materials’ properties and performance in order to cut down the repair cost of a damaged pipeline.

However, the researchers these days are mostly focused on the improvement of the performance of the composite wrapping component and ignoring the function of the infill. In addition, the aforementioned design codes has been overlooking the function of the infill material as one of the load bearing material despite the fact that the infill material is the first material in the repair that are in contact with the damaged section of the pipe. The common understanding on the function of the infill or the epoxy grout used for repair in design up till now is just to fill in the void of the damage in the pipelines without any reinforcement or strengthening role.

As proven by past researches that the infill material in the composite repair system serves the function of load bearing in the load transfer mechanisms. The infill is covered by the wrapping composite and is compressed due to the internal pressure of the pipe. Thus, understanding the mechanical properties of the infill material is very important because it needs to serve as a medium for load transfer from the damaged pipe section to the composite wrap (Lim, 2017).

The compressive strength of the epoxy grout can be considered high but the brittleness of the epoxy grout will not be enough to handle the internal pressure of the pipe for a substantial amount of time. This situation has been made convenient by the recent development of nano-particle reinforced polymer composites. The nano-particles concerned here are carbon-based nano-particles such as carbon nanotube (CNT) and graphene nano-platelets. These materials are chosen to be the reinforcement in the epoxy grout is because of their exceptionally high aspect ratio combined with a low density and high strength and stiffness. The multifunctional properties of these nano-particles made them excellent prospect as reinforcement for polymeric materials. In spite of their strong mechanical properties, the strong van der Waals' force between the particles made it difficult for a proper dispersion of the individual CNTs in a polymeric matrix (Gojny et al., 2004). Modification of the mechanical properties of the epoxy grout will be more effective with proper dispersion of the CNTs in the epoxy grout (Ci & Bai, 2006; Gojny et al., 2004).

In conclusion, the lack of consideration of infill in the composite repair system needs to be addressed in the design standards of pipeline repair. This is because there are proof that the infill works effectively as the load transfer agent between the pipeline and the composite wrap. This situation has also led to more research about how to improve the performance of the infill to maximize its contribution in the repair system. The usage of the composite wrapping can be reduced in a repair with the infill contributing more in the repair system, hence, reducing the cost of a repair.

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